We frequently also used a small shrimp trawl, but it was quite ineffectual as far as Amphioxus was concerned.

Two species of Amphioxus, *Branchiostoma belcheri* and *B. cultellum*, occur in the Malay Seas; the latter is known from Moreton Bay, Torres Straits and Celebes, while *B. belcheri* has been hitherto recorded from Prince of Wales Islands, Torres Straits, Borneo and South Japan, so that either of these species might with equal probability have occurred at Singapore. There is little of interest to note with regard to the specimens themselves. Dr. Willey tells me that in the adult example the "oral cirri are remarkable for the great size of the sense-papillæ which form long projecting conical processes."

In the young, both before and after metamorphosis, the dilation of the dorsal fin at a point vertically above the anus is very marked (see woodcut). This feature has been noted by Mr. Andrews in Japanese examples, and seems to be a point of difference from the specimens examined by Dr. Günther (*v. Zool. Anz.* 18, 1895, p. 59). In the diagram (Fig. 1), which was drawn from a preserved specimen, the notochord is curved up dorsally at the posterior end. This seems to occur in all the preserved examples I have examined, but it is certainly not constant during life. F. P. BEDFORD.

Zoological Laboratory, University College, W.C.

Indian Corn.

I THINK I can satisfy your correspondent, Mr. Kumagusu Minakata (NATURE, February 22, p. 392) about the "maize." I have not Athanasius Nikitin's travels before me, but I have been over a good deal of his ground—and professionally in charge of it—with the book in my pocket.

We cannot now be sure what cereal he meant by "Indian Corn." Probably the term includes several species of Indian millets, great and small; species of Holcus and Eleusine, perhaps even rice. But *Zea Mays*, though well known along Nikitin's line of march, is not a staple grain there even now, though I understand it to be so used, to some extent, a few degrees northwards.

I do not think that any Anglo-Indian botanist will be found to treat it as other than a Portuguese or Musalman importation from the West. The natives certainly look upon it as an imported plant; like potatoes, tobacco, and several others. I suspect that the native trivial name, *Makā*, implies that some seeds may have been brought to India by pilgrims returning from Arabia.

As to Japan, that country is so much nearer to America, and has so ancient a civilisation and commerce, that I should think it very likely to have received American seeds of maize and of other plants long before the Indian peninsula, though that country is now full of Mexican and Peruvian plants—some thoroughly naturalised—which have come "with the sun."

At one time I thought that there were representations of maize-heads in the Ajantá caves, but I have had to give the idea up, after examination on the spot. W. F. SINCLAIR.

Chelsea, February 23.

Colour of Horses for Service in Hot Countries.

GENERAL DAUMAS, of the French Army, states in his book on the horses of the Sahara that dark-coloured horses bear great atmospheric heat much better than light-coloured horses. I have had many opportunities in India of proving the correctness of this observation; but I have not been able to find a correct explanation of this fact, and would therefore feel greatly obliged if you or any of your readers would give me it.

When the temperature of the surrounding air is much higher than that of the animal body, the fact of a horse's coat being dark would at first glance appear to be a disadvantage, because it would absorb heat faster than if it were light in colour. Its power of radiation is evidently greater than that of heat absorption. The colour of tropical animals, as we all know, is darker than that of animals in colder climates.

In speaking of light-coloured horses, I refer to the coat (hair) and not to the skin. Absence of pigment in the skin appears to decrease a horse's resistance to the effects of atmospheric heat. Respecting this point, I have not sufficient data to make any definite statement. M. H. HAYES.

Rugby, March 3.

An Interesting Case of Resonance.

A CURIOUS example of resonance is to be noticed in Llandingat Church, Llandovery, South Wales. In one of the windows there is a pane of glass which is not very tightly fixed, being free to oscillate with a definite frequency, which happens to correspond to the frequency of the low pedal "G" of the organ. The consequence is that when the service is taken in G, at the end of each of the Responses, Amens, &c., quite a loud buzzing noise is produced by the resonance of the window; and I have seen strangers sitting near the window seem quite perplexed, not knowing what causes the noise.

Llandovery College, March 4. KENNETH MCMURTRIE.

THE RELATION BETWEEN THE PERIODIC CHANGES OF SOLAR ACTIVITY AND THE EARTH'S MOTION.

ONE of the most interesting questions arising from the problem of the sun's activity is that of a possible connection between the varying display of forces on the solar surface and certain phenomena on our planet. The evidence which has been gradually accumulating can hardly fail to convince us of the existence of an intimate, though still mysterious, relation between some of the manifestations of the earth's magnetic forces and the state of dynamic action on the sun. Not only the extraordinary coincidences repeatedly recorded between solar eruptions and terrestrial magnetic storms, but still more the striking synchronism between the varying frequency of solar spots and the observed changes in the display of auroræ, and in the daily oscillations of the magnetic needle clearly point to that conclusion. Scarcely less certain seems to be the fact, confirmed by many recent investigations, that a greater or less disturbance of the sun's surface is attended by corresponding effects upon terrestrial temperature, rainfall, and other meteorological phenomena.

But there appears to me to be good reason for believing that the influence of the solar activity upon our planet is of an even more profound and far-reaching nature than has hitherto been imagined. I shall endeavour here to state as briefly as possible the results of investigations (more fully developed in *Astr. Nachr.* No. 3619) which have led me to conclude that the period of solar activity can be distinctly traced in the minute residuals which it has not hitherto been possible to eliminate from the observed values of the earth's elements. We are thereby led to infer that the same unknown force which apparently plays so important a part in the meteorology of the sun, acts upon the motion of the earth to such a degree as to produce perturbations which, though minute, are yet of considerable importance from a theoretical and even practical point of view.

As regards the variation of the spot-phenomenon, all the material here required could be taken from Wolf's *Astronomische Mittheilungen*. The chief results which we owe to the never-tiring zeal of this eminent astronomer, and to his intense devotion to this particular branch of astronomical science, are too well known to require, for our present purpose, more than the remark that there are two well-defined periods in the spot-development, the shorter embracing, on an average, about eleven years, and the longer covering, in Wolf's opinion, nearly six times that interval. These two periods are equally important for the following investigation, the curves of the residuals showing the influence of the greater cycle not less distinctly than that of the shorter one. To mention some of the principal features of the "great" spot period—this being probably less familiar to men of science than the eleven years cycle—it may be stated that this curve rises from a minimum near the middle of last century to a high maximum in 1783, then rapidly descends to a low minimum in 1816, attains subsequently another high maximum in 1838, descends again to a moderate minimum in 1861,

rises to a small maximum about 1873, and eventually falls to a low minimum in 1888, from which it has since been steadily proceeding to higher values, so that another maximum may be expected in the near future.

Now, to prove our assertion as to a connection between the periodic changes of solar activity and the motion of our planet, we shall, in the first place, consider the changes in the mean obliquity as observed at Greenwich from Bradley's time up to 1896. If, besides the gravitational effects produced by sun, moon and planets, no other perturbing force were acting on the earth-spheroid, the observed values of the mean obliquity should be found to decrease uniformly with the time, this "secular variation" being due to the perturbations produced by the planets. The measured arcs of the obliquity would then be very nearly represented by Leverrier's formula

$$\epsilon = \epsilon_{1850} \quad 0''\cdot 47594\,(t - 1850).$$

Owing to the uncertainty of the values of the masses adopted for some of the perturbing planets, the numerical factor in this equation may have a somewhat different value. But the differences between the observed arcs of the obliquity and the values derived from Leverrier's equation ought in any case to be found to increase or decrease uniformly with time. This, however, is far from being the case, as may be readily seen from the accompanying diagram, in which the abscissæ are represented by the epochs of observation, and the ordinates by the differences Observed Obliquity *minus* Leverrier. The data from 1757 up to 1812 are taken from Prof. Newcomb's treatise, "Elements of the Four Inner Planets, &c., Washington, 1895." Since 1812 the data are deduced directly from the annual Greenwich observations. In order to eliminate any possible influence of the shorter sun-spot cycle, which shall be investigated separately later on, these annual values are combined into groups comprising twelve years of observation. This method enables us to study the waves of long period by themselves, independently of the shorter cycle.

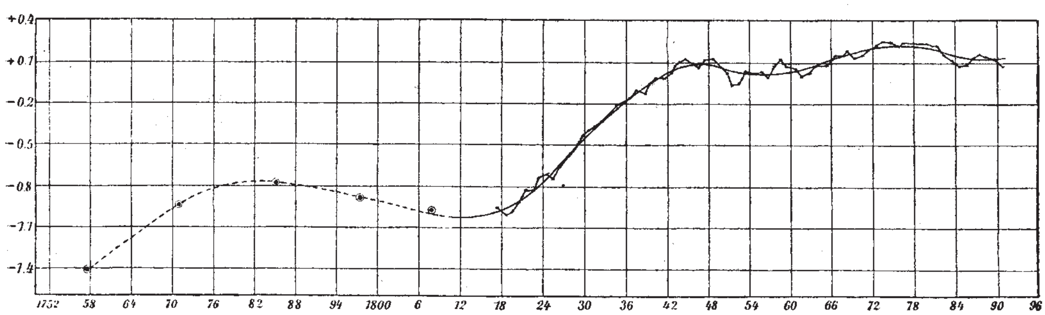

FIG. 1.—Curve of obliquity. (From the *Astron. Nachr.* 3619.)

Here, then, it will at once be seen that the observed changes in the mean obliquity cannot be represented by a linear function of the time, but that, besides the secular term, they show three distinct relative maxima and minima. Now the remarkable feature about these turning points is that their positions agree almost absolutely with those exhibited in the "great" sun-spot period. The two high maxima about 1780 and 1840, as well as the very low minimum in 1815, nay even the less pronounced oscillations indicated by the curve of solar spots, are also most clearly recognisable in the curve of the obliquity represented in Fig. 1. In view of so remarkable a coincidence, the observed changes in the obliquity may be closely represented by the introduction into Leverrier's formula of a term depending on the great sun-spot period. If this term, after being evaluated for all the epochs of observation, is subsequently subtracted from the single values of $\delta\epsilon$ in Fig. 1, the following curve is obtained:

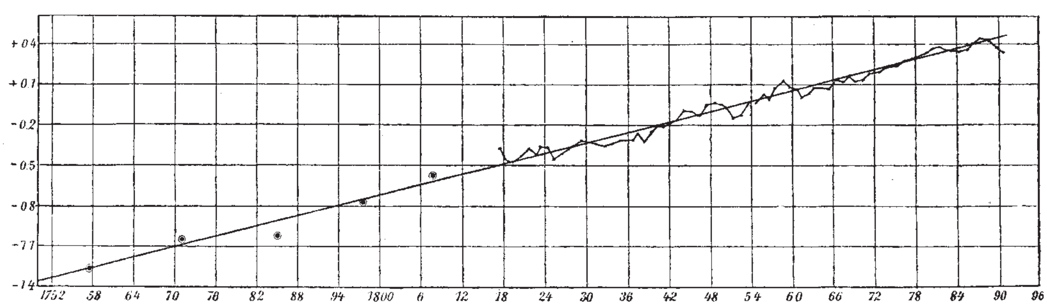

FIG. 2.—Corrected curve of obliquity. (From the *Astron: Nachr.* 3619.)

Now, uniform increase or decrease with time implies that the values of the obliquity should be grouped approximately along a straight line. While this was by no means the case in Fig. 1, it is perfectly true of Fig. 2; and thus it is clear that, taking into account the additional perturbing force due to solar activity, the observed values of the mean obliquity are brought into entire agreement with the deductions of planetary theory.

The significance of the result just obtained is considerably enhanced by the remarkable fact that exactly the same peculiarities appear in the variations of all the other elements of our planet as in those of the obliquity. Not one of the elements, as deduced from observation, can be rigorously represented by a secular term alone; they all show in addition well-marked periodic fluctuations closely agreeing with those of the "great" spot period.

The reality of a distinct, if minute, influence exerted by the changes of solar activity on the earth's motion cannot therefore be doubted, though we are as yet completely in the dark as to the physical causes of this peculiar perturbation.

Now the question arises as to whether traces cannot be discovered of a similar influence upon the motion of the earth-spheroid synchronous with the eleven-years cycle of solar activity. The result obtained on this point receives additional importance from the fact that it throws quite a new light on the theory of a peculiar phenomenon, which has now greatly attracted the attention of astronomers, viz. the *variation of latitude*. The conclusion to be drawn from our investigation points to a close relationship between the amplitude of the motion of the terrestrial pole and the period of solar activity. It may be taken to be clearly established that the radius of the circle described by the pole of instantaneous rotation is greatest at times of sunspot-minima, and smallest at spot spectra during a spot-cycle, the maxima and minima of the spectroscopic curves showing indeed, so far as observations go, a perfect synchronism with those of the curve of latitude-variation.

Judging from these curves the conclusion may be drawn that a very marked influence on the motion of the terrestrial pole of rotation is exerted by a force varying synchronously with the display of spots on the solar surface. Chandler's data previous to 1856 have not been included owing to their incompleteness. But it ought to be mentioned that the correspondence with regard to the positions of the maxima and minima is quite as certain as in the interval exhibited in the above curves. The sun-spot maximum in 1838 is followed by a minimum of the semi-amplitude in 1840, while the next sun-spot minimum in 1843 is succeeded by a very pronounced maximum of the semi-amplitude in 1845. Judging from the epochs of the maxima, the amplitude of the latitude variation completes three full periods in

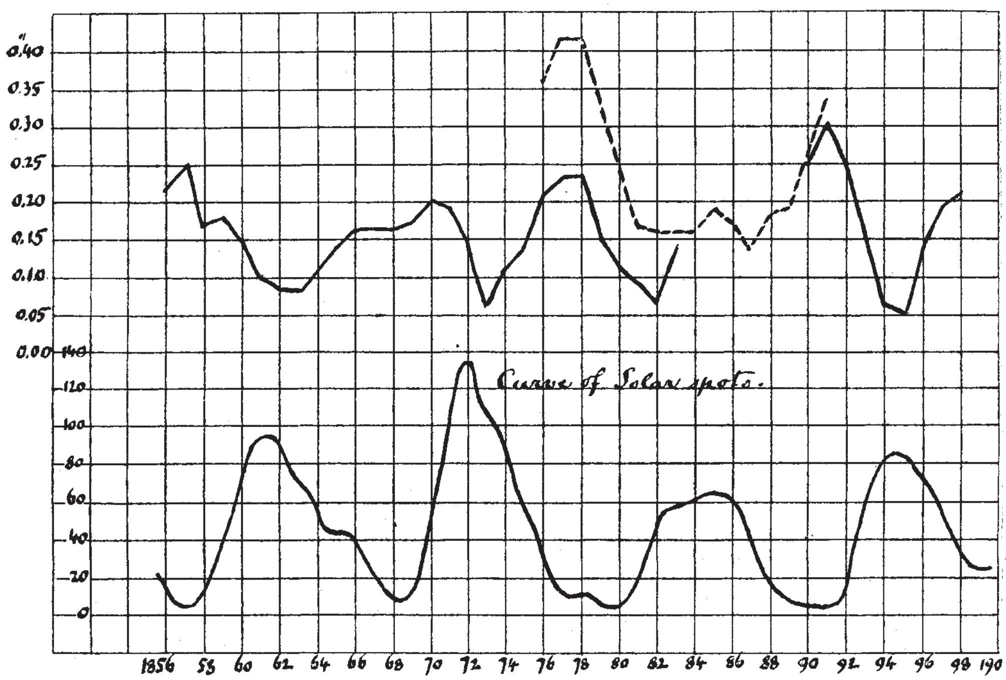

FIG. 3.—Curves of variation of terrestrial latitude, and of solar activity.
The upper curves represent semi-amplitudes of latitude-variation. ——— Chandler. - - - - Nyrén.

times of maximum-displays of solar spots. This correspondence is found to hold true for the whole interval of about sixty years now covered by Dr. Chandler's investigations. The subjoined diagram may help to give a clear idea of this peculiar relation, the first curve showing the semi-amplitudes of the latitude-variation for every year from 1856 to 1898, as deduced from Chandler's curves in *Astron. Journ.* Nos. 277 and 446, and from Dr. Nyrén's values communicated in *Publications de l'Observatoire Central Nicolas*, Série ii. vol. ii.; while the second curve indicates the spot-frequency according to Wolf during the same space of time. As the latitude-phenomenon has been found to lag behind the spot-curve by an interval of about 1·5 years, the latter curve has been shifted one and a half years in the forward direction, in order to establish an agreement between the positions of the maxima and minima of the two curves.

Attention may here be drawn to Sir Norman Lockyer's discovery that a similar lag can be traced in the curves representing the changes in the lines widened in sun- thirty-four years; while the epochs of the minima make this figure only slightly less, viz. thirty-two years. Hence the period of the amplitude is found to be eleven years.

On the whole, then, we are confronted by the fact, so distinctly brought out by observation, that the motion of our planet reveals traces of the action of a force, the intensity of which can be measured by the state of activity on the solar surface. No doubt, the perturbations caused by this force are extremely minute as compared with the gravitational effects exerted on the earth-spheroid. But still, in the present state of our theoretical knowledge regarding planetary motion, and with the high degree of perfection now attained in the art of astronomical observation, such minute quantities are of considerable importance. This is, for instance, sufficiently illustrated by the derivation of the solar parallax from the secular variations of the obliquity and the node of Venus. The value for this constant, as found after eliminating the perturbing effect of the new solar force from the secular variation of the obliquity, is $\pi = 8''\cdot802$, a result which is in perfect

accordance with Newcomb's value obtained from other sources. The great difficulty, by which this distinguished man of science found himself embarrassed in this part of his work (see pp. 158–159 of the treatise quoted above), so much so, indeed, that he well-nigh despaired of arriving at a final conclusion as to the value of π to be adopted, has now disappeared. The values for the masses of the earth, $m(♁ + ☾) = 1 : 327923$, as well as of Venus, $m(♀) = 1 : 414991$, as derived from the secular variations, may thus be accepted with confidence.[1] This is one example showing the theoretical importance of the phenomena here discussed; possibly the results arrived at may be eventually found to contribute towards removing other difficulties still connected with the theory of planetary motions.

We are, it seems to me, fairly warranted in assuming the force acting in such a peculiar way on the motion of the terrestrial pole to be identical with that which exerts its influence on the secular variations. As regards the nature and origin of this force, there is a wide field for speculation. A suggestion to which I was led by a discussion on this subject with my colleague, Mr. G. Clark, of this observatory, and which seems worthy perhaps of further investigation, is that the force may stand in some connection with the still very mysterious phenomena of the earth's magnetism. There is certainly one fact which lends some support to this hypothesis, viz. the eccentric position of the earth's magnetic poles. Joule's well-known experiments on magnetic strain in iron bars suggest the idea that something similar to the molecular displacement in the iron bar may take place in the body of the earth with regard to its magnetic axis. Such a strain along the axis of maximum magnetic moment would almost necessarily cause a displacement of the axis of figure with regard to the axis of rotation. Only so long as the total magnetic potential of the earth was not subject to alterations could this displacement remain constant. In that case the pole of rotation would describe a circle with a *constant* radius round the pole of figure. But there are facts which force us to assume that the potency of the earth's magnetic forces varies with the state of solar activity, and that consequently the molecular displacement in the direction of the magnetic axis varies accordingly. The most striking fact in this respect is the increase of auroræ with an increasing number of solar spots. Now, if we were to consider auroræ as discharges of electric force gradually accumulated in the earth's interior, the strain in the direction of the magnetic axis should have abated after such a discharge, and the pole of figure should therefore approach the pole of instantaneous rotation. This, then, would explain the fact that the semi-amplitude of latitude-variation is smallest after a maximum display of solar spots. How far this hypothesis is able to account for other phenomena brought out by observation must be left to future research.

J. HALM.

Note.—In a very interesting note in *Monthly Notices*, March 1898, Mr. Thackeray investigates the effect of the latitude-variation on the longitudes of the sun as well as on the arc of the obliquity. It appears from his result that the correction to the sun's longitude due to the motion of the pole has an amplitude two and a half times greater than that to the obliquity, cosec. ϵ being almost exactly 2·5. Now from Prof. Newcomb's and Mr. Thackeray's tables showing the corrections to the right ascensions of the sun relative to the stars, as derived from Greenwich observations, I have computed the numerical effect of an error produced in the sun's longitude by an increase from 0 to 10 in Wolf's relative spot-numbers. Assuming Prof. Newcomb's weights assigned to the observations, I obtained $\Delta\lambda = 0''{\cdot}4457 \pm 0''{\cdot}0523$, and consequently $\Delta\lambda \sin \epsilon = 0''{\cdot}1775 \pm 0''{\cdot}0209$. On the other hand, the value previously found for the obliquity in *Astr. Nach.* 3619, was $\Delta\epsilon = 0''{\cdot}1703 \pm 0''{\cdot}0145$. Hence the result that the effect of the force varying with the great spot-period is in point of amplitude exactly analogous to that found by Mr. Thackeray with regard to the phenomenon of latitude-variation. This must, I think, point to the conclusion that those anomalies in the sun's longitude and in the arc of the obliquity which correspond to the great sunspot-period are due to the same force which causes the deviations observed in the motion of the terrestrial pole, that in fact these anomalies are merely another proof of our assertion that the displacement of the pole stands in some connection with the variation of solar activity. The results are derived from two perfectly independent series of observations, the probable errors of $\Delta\lambda$ and $\Delta\epsilon$ being not more than one-tenth of the values obtained; hence the assumption as to the peculiarities elicited from the observations of the sun's right-ascensions and declinations being the result of chance appears to be absolutely untenable.

J. H.

[1] This value of the mass of Venus is in close accordance with that derived by Prof. Backlund from the perturbations of Venus on Encke's Comet.

APPLIED METEOROLOGY.[1]

THE name of Prof. Cleveland Abbe is indelibly associated with the onward progress of meteorology in the United States, whether in respect of its commercial and general utility, or on the severer but not less interesting side of dynamical investigation, to which we must look for any theoretical advancement. In the organisation of an immense service, the observations and returns of which cover a large field in the applied science, he has played a yeoman's part; and further, by his translations of many important mathematical papers, he has stimulated study, and given to his countrymen the opportunity of familiarising themselves with the difficult theory which Helmholtz, Hertz, Kirchhoff and others have developed, and on which the perfected science must eventually be based. It seems fitting, therefore, when one of the States—in this case, Maryland—proposes to advance beyond the mere accumulation of meteorological data, and is prepared to foster the study and discussion of special problems connected with climate and its effects, to devote funds for the prosecution of certain lines of research and investigation, that he should be selected to indicate the direction in which study can be most profitably turned with the view of benefiting every human interest. We at least may congratulate ourselves upon the selection, for the outcome has been to collect into an essay of moderate dimensions a list of the most prominent fields of usefulness to which a State weather service can devote itself. We have here a scheme, which though in the first place intended for a particular climate and district, yet is not limited in its scope, and but with few changes may be made to serve as a model for wider areas, and in its fullest application would meet the demands and the necessities of the best instructed meteorologists.

It would be wearisome to give a bare statement of the manifold duties and occupations in which a properly constituted weather service finds itself called upon to take part, and in these pages, fortunately, such a task is not necessary. There may be some who think that weather prediction for shorter or longer periods alone occupies the attention and satisfies the ambition of the meteorologist. To such we commend the list of twenty-nine distinct subjects of enquiry, bearing on every walk of life, assisting every one of the applied sciences, and touching every material interest, that Prof. Cleveland Abbe has put in the foreground of his essay, as additions to the daily storm and weather forecasts, admitted by the least attentive to be the main duty of a meteorological office. But it is needless to say that the author is not satisfied with the mere utilitarian aspect of the science, however valuable the results may be to the agriculturist, the engineer, the mariner, the physician and others throughout the entire circle of the professions. Just as

[1] "The Aims and Methods of Meteorological Work, especially as conducted by National and State Weather Services." By Cleveland Abbe. (Baltimore: Johns Hopkins Press, 1899.)
"The Monsoon Forecast." *The Pioneer*, August 10 and October 23, 1899.